DOCUMENT RESUME

ED 301 218 IR 052 564

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TITLE Prevention and Treatment of Mold in Library Collections with an Emphasis on Tropical Climates: A Ramp Study.
INSTITUTION United Nations Educational, Scientific and Cultural Organization, Paris (France). General Information Programme.
REPORT NO PGI-88/WS/9
PUB DATE Jun 88
NOTE 89p.; Photographs will not reproduce well.
PUB TYPE Guides - Non-Classroom Use (055) -- Reports - Descriptive (141)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Climate; Climate Control; Emergency Programs; *Environmental Influences; Humidity; Library Collections; *Library Equipment; *Library Materials; *Library Planning; Nutrition; Poisons; *Prevention
IDENTIFIERS *Fungi; *Tropics; United Nations Economic and Social Council

ABSTRACT

This study focuses on the prevention and basic treatment of recurring mold growth in tropical climates where library-wide environmental control is not always possible. The introduction discusses major climatic groups; the effects of climate on specific materials found in library resources; and the range of options for modifying the environment. The next six chapters deal with the following topics: (1) the structure and nature of mold, and the environmental and nutritional factors in their growth and survival; (2) implications of the mold problem in the library setting; (3) prevention of mold growth in the library environment; (4) the traditional chemical approaches used to treat mold growth, i.e., fungicides and fumigation, and concerns in their use; (5) treatment options that might be used, based on an analysis of the problems and the nature of the material that is affected; and (6) a list of equipment and supplies for dealing with the problem. References to the literature cited appear at the end of each chapter. The final chapter provides a selected bibliography of 76 references. (CGD)

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Prevention and treatment of mold in library collections with an emphasis on tropical climates: a Ramp study

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General Information Programme and UNISIST

United Nations Educational,
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Paris, 1988

IR052524

Original : English

PGI-88/WS/9

Paris, June 1988

PREVENTION AND TREATMENT OF MOLD IN LIBRARY COLLECTIONS WITH AN EMPHASIS ON TROPICAL CLIMATES : A RAMP STUDY

prepared by

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Recommended catalogue entry :

Wood Lee, Mary
Prevention and treatment of mold in library collections with an emphazis on tropical climates : a RAMP study / prepared by Mary Wood Lee [for the] General Information Programme and UNISIST. - Paris : Unesco, 1988. - 81 p ; 30 cm. - (PGI-88/WS/9)

I - Titre

II - Unesco, General Information Programme and UNISIST

III - Records and Archives Management Programme (RAMP)

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PREFACE

In order to assist in meeting the needs of Member States, particularly developing countries, in the specialized areas of Archives Administration and Records Management, the Division of the General Information Programme has developed a long-term Records and Archives Management Programme - RAMP.

The basic elements of RAMP reflect and contribute to the overall themes of the General Information Programme. RAMP thus includes projects, studies and other activities intented to :

- develop standards, rules, methods and other normative tools for the processing and transfer of specialized information and the creation of compatible information systems ;

- enable developing countries to set up their own data bases and to have access to those now in existence throughout the world, so as to increase the exchange and flow of information through the application of modern technologies ;

- promote the development of specialized regional information networks ;

- contribute to the harmonious development of compatible international information services and systems ;

- set up national information systems and improve the various components of these systems ;

- formulate development policies and plans in this field ;

- train information specialists and users and develop the national and regional potential for education and training in the information sciences, library science and archives administration.

The following study not only treats the structure of mold, the environmental and nutritional factor, but also its implications for library materials. It emphasizes the importance of prevention and methods of treatment and the importance of the equipment. It also includes illustrations and an important selection of bibliographical references.

Comments and suggestions regarding the study are welcomed and should be addressed to the Division of the General Information Programme, UNESCO, 7, Place de Fontenoy, 75700 Paris, France. Other studies prepared as part of the RAMP programme may also be obtained at the same address.

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ACKNOWLEDGEMENTS

The author would like to thank Bonnie Jo Cullison, of the Newberry Library, Robert Weinberg of Graphic Conservation, and Gary Frost who read the manuscript at various stages, and whose suggestions and encouragement were instrumental in completing the work.

Additional thanks to Lynne Gilliland of the Smithsonian Institution for micro-photographs and to the staff and member institutions of the Pacific Regional Conservation Center who indulged my early fascination with fungi.

Special thanks are due Merrily Smith of the Library of Congress, for the opportunity to undertake this study, and for her patience with the numerous delays.

I. INTRODUCTION

This study is intended primarily as a practical guide to aid in the prevention and basic treatment of mold growth in tropical climates where library-wide environmental control is not always possible, and mold is a recurring problem. Even in more temperate climates, outbreaks of mold may occur as a result of flooding or localized environmental control problems. Increased concern over the toxicity of many of the standard fumigants has led libraries and museums to re-examine existing policies which rely primarily on chemical treatment of mold outbreaks. It is increasingly apparent that more attention must be given to prevention and alternate treatments in order to protect not only collections, but staff and patrons as well.

To be concerned with the preservation of materials in tropical climates is to be concerned with the study of:

- Climate.
- The effects of that climate on specific materials.
- The widest possible range of options for modifying the environment.

CLIMATE

There are five major climatic groups, based on annual rainfall and temperature, with sub-groups based on variations within these parameters. Alphabetic formulas have been developed which constitute a short description of the chief characteristics of specific climates. As defined by Trewartha[1] the capital letter A identifies all humid tropical climates. In Type A climates, rainfall is in excess of 60

inches per year, and is usually over 100. In some places rainfall exceeds 400 inches per year. Temperatures average 70-85° F, rarely rising over 90° F and rarely falling below 64° F. The largest of any of the principal climatic groups, Type A climates acccount for approximately 36% of the earth's surface. Lying in an irregular band extending from the Tropic of Cancer in the northern hemisphere to below the Tropic of Capricorn in the southern hemisphere, the humid tropics include both continental land masses and islands. In most areas, relative humidity is high year round, and mold growth in library and archival collections is a recurring problem.

Within the humid tropics (Type A), several distinct climatic types exist. These include the tropical rainforest (Af), the monsoon rainforest (Am), and the tropical savannah (As or Aw). Each climatic type requires a different approach in the modification of the library environment if damage to the collections as a result of mold growth is to be prevented.

The tropical rainforest (Af) climate has no distinctly dry season. Heavy rainfall is evenly distributed throughout the year. The yearly temperature average is between 77 and 80° F. Although the temperature average is not exceedingly high, it is quite constant, with seasonal variations of approximately 5 degrees, and daily variations of about 10 to 25 degrees. The lower night temperatures are sufficient to cause condensation of the humid air, and fog and dew are common. Winds in Af climates are light or non-existent, as these areas are usually located in the belts of calm between the tradewind latitudes. Minimal air movement, intense light and high humidity result in very little natural cooling.

In the monsoon rainforest (Am) climate, the annual rainfall, though heavy, is seasonally distributed, with definate wet and dry seasons. Am climates usually occur on a coastline, and part of the precipitation is due to the thermal effects of the coastal mountains. This is true of many tropical islands as well. Winds are stronger and more regular than those in Af regions, and the yearly temperature ranges are greater, from 12 to 14 degrees.

In the tropical savanna (As or Aw), three temperature seasons are recognizable: a cooler dry season (temperatures averaging about 80° F); a hotter dry season (temperatures sometimes exceeding 100° F) just before the rains; and a hot, wet season during the rains. The use of s or w in the designation depends on whether the dry season occurs in the summer or the winter. Wind, temperature and rainfall are all transitional, varying with the season.

The best general guide to understanding the climate of a particular area is a good atlas, which will contain numerous specialized maps of the world's climatic regions, with detailed charts on temperature and relative humidity at different seasons. More specific information is available from national and local meteorological agencies.

In tropical climates, the environmental standards so widely recommended in Europe and the United States (temperatures of 68 to 72° F and a relative humidity of 50% ± 5%) are difficult, if not impossible, to achieve and maintain. Due to existing building design, high energy costs, difficulties in acquiring and maintaining equipment, and the extreme year round conditions, temperature and relative humidity cannot easily be kept within these limits. In most cases, complete environmental control, which includes the regulation of temperature, humidity, air quality, and light, is possible only if included as part of the design of a new building, and if the commitment to maintain the systems is assured.

Garry Thomson, one of the foremost authorities on environmental control in museums, in a paper presented at the Asia-Pacific Seminar on Conservation of Cultural Property held in New Delhi in 1972, said: "We are told that museums cannot afford air conditioning. For important museums this is nonsense in any country where we see springing up hotels and business offices which are expensively air conditioned."[2] Certainly with regard to long term goals and planning, this is true. Full control of the environment should be the long-term goal of all library and archive administrators. However, it fails to acknowledge

the economic and political realities with which the museums and libraries in developing countries must deal. Until complete environmental control is possible, less comprehensive methods of modifying the existing environments must be employed.

MATERIALS

There is no question that organic materials, which constitute the bulk of library collections, are particularly vulnerable to the upper extremes of temperature and relative humidity and to the chemical, biological and microbiological deterioration that so often accompany them. Nevertheless, a full understanding of the factors involved in deterioration, combined with careful planning can do much to alleviate the negative impact of adverse environmental conditions. It is imperative that librarians use all the resources available to them, and that solutions to environmental problems be tailored to meet individual needs. Ill-advised choices or an over reliance on technology alone can make a difficult situation even worse.

During and after World War II there was a great interest in the effect of tropical climates on a wide variety of materials.[3] Alarmed by the extreme deterioration of paper, leather, textiles and metals on the Asian and Pacific fronts , both the United States and Great Britain devoted a good deal of government funding and considerable effort to studying the causes and prevention of environmentally-related deterioration . At the time, much energy was poured into the study and development of various preservatives which, if applied to materials, might reduce the effects of the environment. Much less attention was devoted to methods for the control of that environment. By the mid-1950's government funding had largely ended, and research into materials, prevention and treatment slowed. Unfortunately, most of the fungicides and biocides recommended at that time are now known to be toxic to man as well as to mold and other pests. Moreover, much of the current research is directed toward the development of ever more sophisticated environmental control systems, limiting its applicability. For those concerned with the preservation of cultural property today, whether in museums, libraries, or archives, modification of the environment is often the only viable option.

MODIFYING THE ENVIRONMENT

Within the context of this study, it may be useful to define two of the terms which will occur throughout the work, and which are not to be considered interchangeable.

Environmental control is used to indicate a system which will monitor and regulate both temperature and relative humidity, consistantly maintaining them, in balance, within pre-established guidelines.

Environmental modification is used to indicate the alteration of one or more of the variables in the environment. It is not self-monitoring and requires constant adjustment in order to maintain the desired balance. Window air-conditioning units, portable dehumidifiers, and fans are all environmental modification, not environmental control.

While a full range of control, modification and emergency treatment options will be discussed in this study, emphasis will be given to measures that do not rely on elaborate enviromental control systems, extensive fumigation or major conservation treatment of seriously damaged materials. Disaster planning and procedures will be discussed only in the context of the prevention and treatment of mold.

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II. MOLD

It may seem, in what follows, that an inordinate amount of attention is devoted to the structure and nature of mold. Because fumigation has for so long been the treatment of choice, there seems to be a feeling that information regarding the organism itself is irrelevant. Moreover, librarians are understandably frustrated by literature which urges them to consult a microbiologist or entomologist in order to identify the offending species. While it is to some extent true that one need not identify precisely the mold involved in order to treat it, an analysis of the problems associated with mold growth and the selection of an appropriate treatment must be based on some understanding of the organism. As Allsopp notes, it does not require a specialist to determine the hazards posed by most organisms. One can, after all, "observe a mouse or a bird and state accurately whether it is dead or alive. Organisms such as these can be seen and identified, and vital signs are easily recognized. Mice rarely lie stiff on their backs, motionless, with their feet in the air when they are alive. Micro-organisms, however, pose problems..."[1]

Because the nature of molds is so poorly understood, their appearance is often cause for disproportionate alarms and excursions, with cries for institution wide fumigation, the formation of committees, and often, a lamentable level of inaction. Much of the older and some of the current literature recommends that items be isolated in plastic bags, to await fumigation or other treatment or that the mold be brushed from the surface of the item. Once the structure of the mold organism is clearly understood, and the staff has some idea of the reasons for its occurrence and growth, recommendations in the literature can be more

accurately evaluated, and informed decisions can be made as to the appropriate treatment. For example, in the above instance, placing the item in a plastic bag at the first visible sign of the mold will simply create a micro-climate that may actually accelerate the growth of the colonies, possibly doing serious damage while treatment is awaited or debated. Simply brushing the mold away will only remove the visible portion of the mold, scattering the spores, and pressing the invisible sub-structure down onto the surface of the item. Treatment techniques will be dealt with in detail in a later section, but are mentioned now to stress the importance of this section and the section that follows. Together they will provide the basis for informed decision making. The mold organism must be clearly understood, since the nature of mold, the reasons for its occurance, and the stage of its development will determine the specific treatment and the time frame within which action should be taken.

STRUCTURE OF MOLD

Mold is the commonly used term for cryptogamic fungi, i.e. fungi that propagate by means of spores. The prevention of mold growth through the exclusion of mold spores from the environment is not a viable option. Mold spores are ever present in virtually all environments and the distribution of species is relatively uniform world wide. The extreme micro-biological deterioration that occurs in tropical climates differs from that in temperate climates only in degree, not in kind. It is the result of optimum conditions rather than unique or particularly virulent strains. The isolation and identification of large numbers of fungi found in the tropics have failed to reveal any genera that can be singled out as either characteristically tropical, or limited to tropical areas.[2]

The majority of molds of concern to the librarian and the archivist are made up of two different structures, vegetative and reproductive. The vegetative portion is characterized by a branching of colorless threadlike filaments called hyphae. These hyphae, collectively referred to as mycelium, branch out across the paper or other substrate and are quite invisible to the unaided eye. They form

Illus. 1

Asperigillus (approx. 200x) Although mold appears to the unaided eye as a felt-like mat, with magnification, the individual plants are clearly visible, the conidiophores appearing to float like spheres above the surface of the item.

Illus. 2

Aspergillus (approx. 500x) At approximately 500x, the stem and head of the conidiophores can be seen, each plant bearing thousands of phialides and spores, the reproductive elements.

the root system of the plant. Their presence preceeds the appearance of the visible mold growth. Once the mycelium are established, the mold reproduces by spores produced externally on the hyphae. In most of the mold which are of concern to librarians, the individual hyphae produces stalks known as conidiophores, which in turn produce phialides, which are the colored components of the mold. These are the reproductive structures.

Molds are admirably equipped by nature for survival. Of the spores produced, there are two general types. Some spores are produced rapidly and in large numbers, but have very little resistance to drying, sunlight and other adverse environmental factors. They make possible the rapid growth and development of colonies when conditions are favorable. Other spores are much more resistant to unfavorable conditions. These "hold-over" or resting spores enable the organism to survive over long periods of adverse conditions.[3]

In many molds, the flowering stage, which is evidenced by colored phialides is preceeded by a soft, grey, fuzzy growth visible to the unaided eye. If the mold is removed at this stage, before the flowering begins and the effect on the substrate is most severe, mold stains seldom occur. This is not to say that the substrate will not be damaged, but the damage may be greatly reduced.

The exact cause of the stains often seen after mold has been removed or in dead or dormant colonies is difficult to determine, as is the time frame within which the staining occurs. While staining usually seems to be the result of mature colonies that have been allowed prolonged growth and development, certain molds are known chromophores, and may produce extensive color changes in the substrate, even though their growth is limited.[4] Belyakova has identified numerous genera which produce stains on paper due to the production of pigments by the fungi or to the mycelium, which penetrate the paper. The color of the stains is not an accurate guide to the specific mold which caused it. Penicillium frequentans for example produces yellow stains in some instances, pink stains in others.[5] Much work remains to be done in

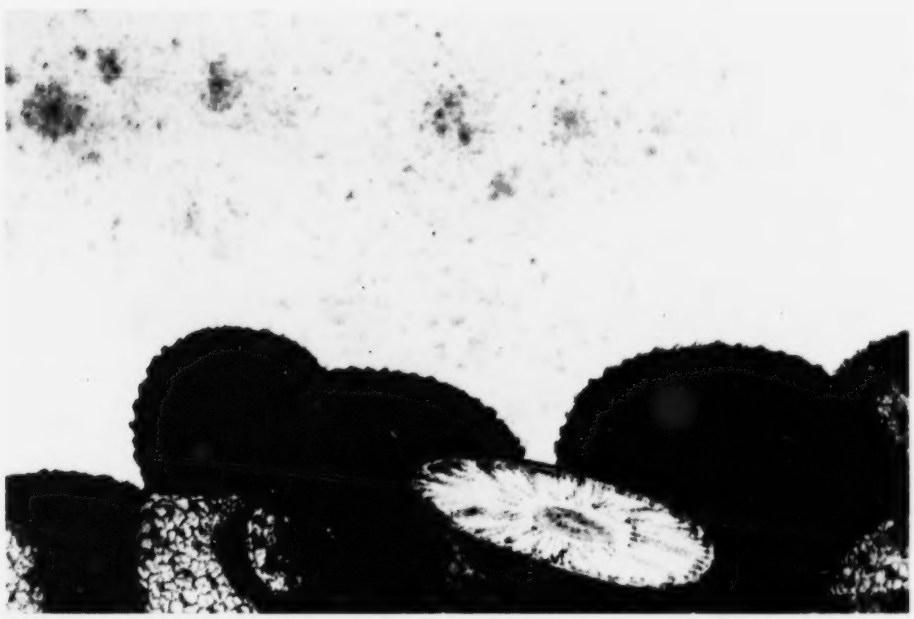
order to determine whether staining is produced by the molds digesting the nutrients in the substrate and excreting the by products, as some sources suggest, as a result of acids produced during the hydrolysis of the cellulose, or simply by chromophores present in the cells of the mold itself.

Illus. 3

Mold, which grows on the surface, may produce stains which are <u>in</u> the paper. Such stains can be seen on the right of the colony where the mold growth has been removed. Stains can only be removed by chemical treatments which should be undertaken only by conservators.

In addition to the cryptogamic fungi, which are the primary focus of this study, two other types of mold may cause damage to library materials. Foxing, the common designation for the small brown spots that appear in old papers, is a mystery yet to be resolved. Its exact nature and cause remain uncertain. Dard Hunter noted that books papers before 1501 seldom showed signs of foxing and attributed its occurance after that date to the increased demand for paper which caused paper makers to reduce the amount of water used and did not allow enough time for "the proper cleansing of the fibers."[6] In the 1920's Beckwith found that foxing was usually associated with the presence of iron in the paper,[7] leading others to believe that it is the result of metals left in the paper during manufacture, and that it's incidence coincided with the invention of the Hollander beater in the late 17th century. While trace elements of iron may be a necessary component, the presence of foxing, called <u>hoshi</u> (stars), in very old Japanese papers produced using traditional beating and sheet formation techniques would seem to

indicate that iron left in the paper as a result of Western manufacturing processes is not the sole cause. Though foxing has yet to be produced on demand in the laboratory, many now believe foxing to be a form of micro-biological growth. In 1984, a Japanese researcher, using a scanning electron microscope isolated and identified the fungi Aspergillus glaucus and Aspergillus restrictus which he believes to be the cause of foxing.[8] Whatever the cause, it seems certain that its incidence is increased by high temperatures, high humidity, and by proximity to poor quality materials. That it does indeed damage paper is evidenced by differential wetting characteristics of foxed papers during conservation treatment.



Illus. 4
Detail of botanical plate with foxing. Foxing, like mold staining, is in the paper and can only be removed by chemical treatments. Librarians should learn to distinguish active or dormant mold growth, which can and should be removed, from foxing.

Slime molds, which are relatively rare on finished materials, most commonly occur during paper manufacture. These organisms are usually destroyed by various chemicals and by the heat of the drying process. Their presence however may serve to weaken paper and make it more vulnerable to deterioration when combined with adverse environmental conditions later.

ENVIRONMENTAL AND NUTRITIONAL FACTORS IN GROWTH AND SURVIVAL

Most of the information available on the growth and development of mold is derived from laboratory cultures rather than on site studies. This information is therefore not always relevant to the growth and development of the same organism in the library environment. It is however, accurate to say that three factors are essential for the growth and survival of molds: the correct temperature, adequate moisture, and proper nutrients. St. George[9] notes that it is a common misconception that light is required for mold growth. Unlike most plants, virtually all molds lack chlorophyl and therefore, light plays no role in their development. Colonies thrive in the dark, since for some varieties, exposure to ultra-violet light is injurious or lethal.[10]

Temperature

There are three critical temperatures for mold, the temperature below which no growth occurs, the temperature above which no growth occurs, and the temperature at which most rapid growth takes place. Most microbial forms grow in temperatures ranging from 59° to 95° F (15° to 35° C), although there are forms which will grow at almost freezing and others which thrive at over 150° F. The average optimum for mold growth is usually stated to be in the vicinity of 86° F. The optimum temperature for the growth of specific molds is difficult to determine, in part because of variables in other environmental conditions, and in part because the culturing of organisms in the laboratory is a very different matter than the growth of the same organism in more natural surroundings.

It should be noted that the temperature below which no growth occurs is not synonymous with the temperature at which the potential for growth is destroyed. Many molds can survive periods of several months at sub-zero temperatures, but are less tolerant of alternating below-freezing and above-freezing temperatures.[11]

Sykes, speaking of bacteria, says:

> Refrigeration at low temperatures...is popularly considered to be fatal to all forms of life. Whilst this

> may be true for the larger forms of organized life, it is certainly not true for the smaller plant life, including micro-organisms....sometimes the death rate is as high as 99% but once frozen at a sufficiently low temperature the surviving cells can be preserved for long periods.[12]

Given the existence of the "hold-over" spores, this undoubtedly applies to molds as well.

Moisture

The amount of moisture required for mold development is seldom addressed in the microbiological literature. In the laboratory molds are cultured in media with a high moisture content, but the precise level is seldom mentioned in their reports. The covered petrie dish creates a microclimate where the mold can flourish undisturbed. With regard to the growth of mold outside the laboratory, sources do indicate that the hygoscopic nature of materials affects the growth of mold. Materials which absorb and hold moisture from the air require lower levels of ambient relative humidity than do less hygroscopic materials. Thus, in a non-laboratory environment, the mold has at its disposal two sources of moisture, the air surrounding the item and the moisture held by the item itself.

Nutrients

The elements required for the growth of fungi include carbon, hydrogen, oxygen, nitrogen, sulfur, potassium, and magnesium. Trace elements such as iron, zinc, copper, manganese, and in some cases, calcium may also be required . Certain of the vitamins are also needed. Most naturally occuring compounds can be utilized by fungi as sources of carbon and energy. Cellulose provides many of these elements, as do animal and vegetable fats and their component acids and glycerine.[13]

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III. IMPLICATIONS FOR LIBRARY MATERIALS

Virtually all organic materials are susceptible to some species of mold and therefore to mold growth. The organic materials in library collections include, but are not limited to: cellulosic fiber; sizes and fillers of starch, casein and gelatine; natural adhesives, including starch paste made from vegetable matter and glues from animal skins; some sythetic adhesives; leather; and the gelatine on negatives and photographic prints. In addition, dust and dirt can provide additional nutrients required by the mold. All of these materials are hygroscopic, that is, they attract and hold moisture.

Despite this overall vulnerability, a variety of factors will affect the actual growth of mold within the library collection. Certain papers, leathers, bookcloths and adhesives are more susceptible to mold growth than others. In most cases the librarian has little control over the composition of the materials in the collection. However, a knowledge of the nature of those materials is necessary in order to make informed decisions as to why the infestation has occurred, how to treat those items obviously affected, and whether it is likely that the problem will spread throughout the collection.

For example:

- o The appearance of mold on only the leather bound books indicates that the active spores are specialized in their nutrient requirements. Since molds are selective, if no cloth covered or paperbound books in the immediate vicinity are involved, emergency treatment can be concentrated on the leather volumes.

- o If the growth appears only around the head cap, or on the edges of the text next to the turn ins on the boards, it is likely that the nutrient source is the adhesive used in the binding.

- o If only a few ranges or a few stack sections in the area are affected, the problem is most likely one of a micro-climate. The affected items can be removed and efforts to modify the environment can be localized to that area.

Innumerable examples could be given, however the point is that a knowledge of the materials, an analysis of the nature of the problem, and an understanding of the interaction between the two can greatly reduce the potential damage.

VULNERABILITY OF MATERIALS

In order to prevent mold growth, or to treat it effectively once it has developed, it is not necessary to identify which of the thousands of genera of mold may be involved. It is however necessary to understand the basic structure of the mold organism and the manner in which it takes advantage of favorable conditions. This means that librarians must assume responsibility for a wide range of knowledge concerning the materials in their collections as well as the nature of the threat in order to make informed decisions regarding appropriate treatments.

Paper - Cellulose, Sizes, Coatings

In 1940, Beckwith and his co-workers isolated 55 different mold cultures from old book papers, including eleven genera, of which Penicillium and Aspergillus were the most commonly found.[1] In the study, spores were removed from the papers, transfered to a culture medium and grown under laboratory conditions. This is not to say that all of them would have been able to use the paper as a medium for growth, but certainly some of the strains of Aspergillus and Penicillium would be likely to attack cellulose or one of the numerous paper additives, sizes, fillers or coatings. At least 180 genera or species of mold are known cellulose destroyers, i.e., they use the cellulose fiber as a nutrient.[2]

Other molds that do not actually consume cellulose may damage paper by weakening the fiber bonding as they feed on other materials in the paper. The fillers, sizes and coatings added to the paper during manufacture to improve printability, texture, color or brightness are a potential source of nutrients, and may include starch, gelatine and casein. Rosin size was found by Beckwith to inhibit fungal growth;[3] however, rosin is acidic and has been found to accelerate the chemical deterioration of paper and its presence is not cause for rejoicing. Very little is know about the various synthetic sizes, as much of the research in this area took place before they were in common use.

Paper in bound volumes is less vulnerable to high ambient relative humidity than unbound paper. Cryptogamic fungi seldom occur in closed volumes under such conditions, but rather on the bindings and on unbound sheets of paper exposed during prolonged periods of dampness. Foxing, on the other hand is commonly found in text blocks.

In cases of flood or other severe wetting, book paper may be considered to be more vulnerable, since the bulk of the volume and the compression of the paper at the spine slow the drying process considerably.

Bookcloth

Many bookcloths, including those of cotton and linen, are cellulosic and are vulnerable to the same range of mold species that affect paper. Like paper, the fillers and coatings added during manufacture provide an additional source of nutrients. The unsized cloth frequently used in bindings from India and Southeast Asia is particularly vulnerable. Because it is often quite thin, the adhesive used in attaching the cloth to the boards often penetrates the weave of the cloth, allowing mold to grow on the surface. Starch filled buckram, commonly used in more temperate climates is also an excellent source of nutrients. Manmade fibers, or natural fibers coated with synthetic resins, i.e., peroxylin cloth and acrylic coated buckram are more resistant to mold, but not entirely immune. No literature was found

regarding the affect of dyes on mold growth, although dyes have been found to have considerable effect on the resistance of textiles to photochemical action (some accelerating deterioration and others providing protection).[4]

Leather

Tanned leather is more resistant to mold growth than untanned leather. Chrome tanned leathers are relatively impervious, vegetable tanned leathers considerably less so. Book leathers are, unfortunately, vegetable tanned, chrome leathers being used primarily in shoes, luggage and other such items.

Studies indicate that mold growth does not affect leather in the same way that it does cellulose. The mold apparently does not attack the hide-tannin complex itself.

> Barghoorn has demonstrated that invasion and destruction of the collagen aggregates of the hide substance does not occur; and Hyde, Musgrave and Mitton have shown that vegetable-tanned leathers suffer surprisingly little damage through even fairly heavy and prolonged mold growth. Experimental evidence indicates that the major cause of tropical deterioration of leather is hydrolytic breakdown due to the high atmospheric humidity and temperature and to their effect on interfiber lubrication, the extent of the hydrolysis being dependent upon the pH of the leather.[5]

Thus, it seems that the components of leather which support mold growth are the lubricants, the conditioning materials and the finish. It would seem from the literature cited above that high ambient relative humidity rather than mold damage is the primary cause of deterioration of leather in tropical climates.

Oiling of leathers, which many libraries have viewed primarily as a cosmetic treatment, may in fact be the most viable way of protecting leather in a tropical environment. Some libraries in tropical climates

have avoided leather dressings, fearing that the use of oils and lubricants would promote mold growth. However, since any resultant mold growth is superficial and causes no structural damage to the leather, and since the application of a leather dressing prevents the hydrolytic damage that is the chief cause of deterioration, the use of leather dressings of appropriate composition should be considered beneficial.

With regard to the choice of a particular leather dressing, experience in the tropics indicates that a very light coat of neatsfoot oil and lanolin, allowed to dry for 24 hours and then buffed with a soft cloth works well. Leather dressings containing wax, including one developed by the British Museum, do not harden satisfactorily in warm humid climates, and the surfaces of treated items tended to stick together when returned to the stacks.

Adhesives

Pastes (made from vegetable starches), glues (made from animal products) and gums (made from vegetable resins) are all subject to mold growth to varying degrees. The use of excessive amounts of adhesives may be one factor in promoting the growth of mold. With regard to the application of adhesives, more in not necessarily better.

Synthetic adhesives, including polyvinyl acetate emulsions (the so called "white glues" which vary enormously in composition and properties), pressure sensitive adhesives on tapes and labels, heat set adhesives such as those used in dry mount papers, and aerosol spray adhesives are more resistant to mold, but not entirely immune. They are solvent based, and therefore dry quickly. However, their poor aging properties and the fact that solvents are required for their removal make them undesireable for the repair of torn or damaged paper.

Despite the possibility of mold, pastes and gums are recommended for mending of paper due to their reversability. Proper application and thorough drying of the adhesive film provided the best protection. Repairs to bindings are perhaps best done with good quality PVA.

Film and Related Materials

All photographic materials have in common a substrate of gelatin which carries the emulsion of silver halide particles that produce the image. The film base may be nitrate, acetate, polyester, glass or paper and the format may be a negative, a photograph, or a reel of microfilm, but all have a gelatin layer. As with the gelatin sizes used in paper, photographic gelatin provides a nutrient for mold growth, which can penetrate the emulsion layer, damaging the image. The polymers that provide the base for contemporary film stock are generally very resistant to fungal attack,[6] however paper and glass supports are both vulnerable. Glass plate negatives can actually be etched by fungi, and combined with the damage to the silver halide layer, can render the negative completely useless.

Gelatin is relatively stable as long as it is kept dry. In high humidities gelatin begins to swell and if exposure is prolonged, becomes sticky. This can occur at relative humidities as low as 60%.[7]

ENVIRONMENTAL FACTORS

The five critical environmental factors for the growth and development of mold in library collections are:

- o The presence of mold spores
- o A source of nutrients
- o Adequate moisture
- o Suitable temperature for a particular variety of mold.
- o Limited air circulation

It is obvious that the first two factors are completely beyond the control of librarians. The presence of spores and the source of nutrients are a given in library collections. Only the last three factors can be manipulated or controlled in order to prevent the occurance of mold growth.

Circulation

Of these three, circulation is one of the most critical, and the most often neglected. The literature often mentions in passing the

importance of good air circulation. Unfortunately, the significance of this factor, particularly in areas where the environment is not temperature and humidity controlled, has been largely overlooked. Air movement causes the evaporation of moisture, lowering the surface temperature. This is evident to anyone who has ever experienced the cooling effect of a sudden breeze on a hot still day. Good air circulation in the library results in the evaporation of moisture, lowers the surface temperature, and alters two of the environmental factors on which mold growth depends.

It is, in general, much less expensive to move existing air around, thereby modifying the temperature and humidity than it is to introduce an artificially created supply of air with characteristics radically different than that of the surrounding air. Good air circulation can do much to reduce the problems associated with lack of control of conditions three and four.

Relative Humidity

Paper, cloth and leather are all hygroscopic, that is, they absorb moisture from the air and retain it. Thus, in humid climates, most materials in the library contain a relatively high percentage of water. In these conditions, even a slight increase in ambient relative humidity is enough for the item to sustain mold growth, if the other requirements are present.

There are several different ways to measure moisture. Absolute Humidity is the weight of water in a given volume of air (g/m^3). Moisture content is the weight of water in any given material (kg/kg). Both of these measurments are variable, i.e., warm air can hold more moisture than cold air, and the moisture content of materials varies with the absolute humidity of the surrounding air. Neither absolute humidity nor moisture content can be effectively determined in a library environment. Therefore, the only useful measure from the point of view of collections maintenance is that of Relative Humidity (RH). Relative humidity is the amount of water in a given volume of air relative to the maximum amount of water air can hold at that temperature, and is expressed as a percentage.

When warm air is cooled it can hold less moisture. This moisture condenses on the surface of items or is absorbed by them if they are hygroscopic. If, for example, at 70° F, the RH is 50%, it requires only a ten degree drop in temperature to raise the RH to 70%. Plenderleith and Werner[8] include a chart which shows the curves relating a reduction in temperature to the corresponding rise in relative humidity. In humid tropical climates lowering the temperature without reducing the relative humidity can result in rampant mold growth, as many institutions have discovered to their dismay after installing a series of window air conditioners in an attempt to improve their environment. While air conditioning does remove some moisture from the air, and is generally adequate in a more temperate environment with a naturally lower ambient RH, in tropical climates with year round RH of 80 to 90%, a window airconditioning unit cannot remove enough of the moisture to prevent the cooled air from reaching the dew point.

The literature contains a variety of recommendations for RH levels that will prevent the growth of mold. They range from a high of 60% to a low of 45%, and seem to have declined steadily over the years. In 1940, Beckwith found that of the molds in his experiment, none would grow at a relative humidity below 75%, even when additional nutrients were added to the culture.[9] While not definitive, this would help to explain why tropical libraries and museums (whose RH is seldom as low as 60%, let alone 45%) are not constantly blanketed in mold. Certainly lower relative humidities are safer, but it is apparent that the incidence of growth can be minimized at significantly higher levels of humidity.

Because relative humidity is so dependant on temperature, all figures are relative, and subject to a number of variables. As seen above, a change in one results in a change in the other and achieving the correct balance is the critical factor.

Temperature

There is a strong inclination to attempt to modify the environment

through changes in temperature alone, in part because temperature is the factor to which human beings are most sensitive. High temperatures do have a detrimental effect on library materials, and these have been so emphasised in the literature that they have tended to obscure the effects of lowering the temperature without regard to the relative humidity. As with most other environmental issues, easy answers and quick fixes tend to create problems that, in the long run, are often more damaging than the original problem.

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7. Fleming, p.363.

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9. Beckwith, p. 331.

IV. PREVENTION

There is no question that the prevention of mold growth is much easier when the library environment is controlled, but the technology for such control is expensive to install and maintain. Modification of the environment though less expensive, is not without cost. Care of collections is as important as acquisition and organization, and should be budgeted by every library and archive. Although there are no panaceas, there are a number of possibilities for environmental modification that will enable institutions to reduce likelyhood of mold damage to collections.

BUILDING DESIGN AND MODIFICATION

If one is fortunate enough to be involved in the design of a new building with state of the art environmental controls, there is ample coverage in the library and museum literature, beginning with Garry Thomson's excellent volume, "The Museum Environment"[1] which should be an invaluable aid to librarians. No attempt will be made here to retrace this ground. Instead, attention will be focused on the modification of existing buildings and the design of new buildings which will not incorporate environmental control.

It should be noted that a building constructed with the idea that environmental controls will be added at some future date is not a viable option. A building designed in such a way that environmental controls can be effectively installed and economically operated in the future, will most probably be insufferable for both users and collections in the meantime. The low ceilings and closed interiors that make environmental control possible create the worst possible environment in the tropics.

By the same token, a building designed to take advantage of natural ventilation makes the installation of a complete environmental control system virtually impossible, or at the very least, astronomically expensive. Decisions regarding the environment must be made early in the planning.

Even without environmental control, good design can do much to reduce the negative impact of the locale's prevailing climate. There is surprisingly little literature available on building design in the tropics. Vance's bibliography[2] lists a scant fifteen pages of references, many 20 to 30 years old. Though the literature is not extensive, working together the librarian and the architect can design a building that will safely house the collection. In building design, it is important that the area's particular type of tropical climate be taken into consideration since the requirements will be different for each of them, though some common denominators do exist.

Location

The various climatic zones discussed in the introduction are important in determining the requirements of a new building, or the best methods for modifying the enviroment in existing structures. Fry and Drew[3] provide additional information on the particular variations between continental and island locations which will be helpful in modifying the environment. Only general guidelines can be included here.

In the tropical rainforest climate (Af) where conditions are relatively uniform year round, temperatures are seldom extremely high (usually less than 90° F), and winds are light or non-existent, the major effort should be concentrated on improving circulation and lowering the relative humidity.

In the monsoon climate (Am) the stronger prevailing winds may be used to advantage for improved ventilation and circulation and more resources can be devoted to lowering the relative humidity, especially during the rainy months.

In the tropical savanna (As or Aw), with three distinct climatic seasons, more elaborate systems may be required. During the dry, hot seasons, dust and dirt will be a particular problem. The building must be capable of being closed against dust during this period, while maintaining adequate ventilation in order to prevent the build up of heat in the interior of the building. The problems associated with extremely high temperatures, dust and desiccation may make air conditioning the most important factor in maintaining collections in these conditions. Because there are two dry seasons and a relatively short wet season, mold may be a problem for only a small portion of the year, or not at all. Every effort should be made to prevent extreme fluctuations in RH between seasons. The utilization of natural ventilation in savanna climates varies from that in the Af and Am climates. Oakley[4] provides several useful diagrams suggesting possibilities for natural ventilation in As and Aw climates.

Structural Considerations in Environmental Modification

Temperature and circulation can be modified directly through building structures. Relative humidity can be modified only indirectly through the effective use of natural ventilation or through technological control which will be discussed later.

Temperature

East and west walls, which receive the brunt of the morning and afternoon sun should be protected and insulated so that the sun's heat is not transmitted to the interior of the building. The roof, which has a high level of exposure to the mid-day sun, should reflect heat and there should be an attic or ventilation space directly below the roof to provide insulation for the interior of the building.

Double wall construction is an excellent way of insulating buildings in the tropics. Air is an effective insulator, and prevents heat from passing through the outer wall to the inside of the building. In many places in the tropics, the hollow cement block is a staple of the building trade. It provides an economical, though not always aesthetic, building material, and provides adequate insulation for the

interior of the building. A true double wall construction is more effective, but considerably more costly. This construction is also used effectively in temperate climates where extremes of cold and heat make long term operating costs for environmental control a primary consideration.

The brise soleil is a variation on the double wall. It may be designed as part of the building, or attached to the facade of existing buildings. Though not as effective as a double wall, it provides protection by absorbing the sun's primary radiation. It also reduces the light levels inside by shading the windows, and allows windows to remain open even in the rainy season. It may cover the entire wall, part of the wall, or in some cases, only windows though this latter construction is considerably less effective in reducing the transmission of solar radiation.

Shading of exposed walls can take a number of other forms, including exterior landscaping with trees and shrubs, the extension of over hanging roofs, and the installation of exterior canopies. The use of interior blinds, curtains or louvres can also reduce the transmission of heat through window glass. Kukreja[5] provides a table evaluating the effectiveness of various shading devices based on their reduction of total heat gain, efficiency in ensuring cross ventilation, and the percentage of natural light resulting from that particular form of control.

Glass both transmits and intensifies heat. Large windows in tropical climates can significantly increase interior temperatures, yet are incorporated into many buildings for aesthetic reasons. Ultra violet and heat absorbing films are effective in reducing heat and UV light without obscuring views or lowering the light levels too greatly.

High ceilings are a common feature of older buildings in the tropics and are an effective means of diffusing interior heat. As the warm air rises, it can be pulled out of the building with ceiling or attic fans or through windows placed directly beneath the roof overhang.

Ventilation

In general, buildings in tropical climates should be oriented in such a way as to take advantage of any prevailing winds and designed so that cross ventilation is possible in all areas of the building.

Even buildings designed to utilize natural ventilation will require back-up systems of mechanical ventilation for those times when prevailing winds fail or shift.

Placement of windows is a principle means of assuring adequate air circulation, once the orientation of the building has been determined. Kukreja[6] provides excellent diagrams of interior air movement for various window placements. These are useful not only in the design and modification of buildings, but in anticipating problems and determining stack arrangements. He notes that a single window serves no purpose as far as interior ventilation is concerned, and that if modifications are to be made, the best results are obtained by placing windows on opposite walls to insure cross ventilation. Enlarging the outlet window opening results in a definate increase in interior air movement, even when the inlet window remains unchanged. Circulation is also increased significantly by increasing the height of narrow inlet and outlet openings. He also compares the circulation figures for various window areas in relation to floor area, demonstrating that air movement peaks when window openings are equal to 25% of the area's floor space.

Louvred windows can provide excellent ventilation, and are common in the tropics, but are difficult to seal against rain and insects, and their use is best combined with other window treatments. All open windows should be screened with well fitted, fine mesh, fiberglass screens. Placement of the screens on the inside of the windows will facilitate their removal for cleaning, particularly if there is a brise soleil on the outer wall.

If the existing building has high ceilings, the installation of ceiling fans is an excellent investment. Used in conjunction with

standing floor fans, or window fans adequate air circulation can be maintained at a relatively modest cost even in Af climates where there is very little natural air movement.

INTERIOR MODIFICATIONS IN EXISTING FACILITIES

In addition to the modifications in building structure which will reduce the transmission and retention of heat and moisture, modifications can be made in stack and storage areas which will benefit the collections.

Location of Stack and Storage Areas

Because of the high water table common in tropical climates, buildings are usually constructed without the basements and sub-basements common in temperate climates. In the event that the building does have one or more levels below ground, every effort should be made to avoid using these areas for either stacks or storage of unused collections. Sub-surface areas are difficult if not impossible to adequately seal, and moisture from the ground will wick through the walls. Even if walls are coated with moisture barrier sealants there is a tendancy for moisture and salts to build up below the surface of the coating until the surface of the wall and the coating begin to flake, (a condition known as spalling) exposing the interior of the wall and allowing the moisture to come through into the interior of the building. Adequate ventilation is also difficult to maintain. These factors result in warm, damp, still air and virtually assure the growth of mold.

Even if underground areas are not used for storage, both walls and floors should be sealed as thoroughly as possible to prevent the elevation of relative humidity throughout the building. Frequent inspections should be made to monitor conditions in these areas, and staff should be aware of potential trouble spots in the building.

Sealed interior rooms should also be avoided, unless they can be environmentally controlled by mechanical systems to control both temperature and relative humidity. Such areas should be monitored regularly. In buildings designed with such areas, ventilation may be

improved by replacing solid interior walls with a half wall of louvred windows which can provide cross ventilation either naturally or with the use of fans.

Stack Arrangement

Stacks should not be placed directly against exterior walls as heat and moisture transfer is greatest there, and circulation will be severely limited. Even a foot of air space between the wall and the stack will improve circulation and prevent condensation of moisture on the wall from creating a micro-climate.

Stacks should be arranged parallel to the air flow, so that the prevailing air movement is across the spines of the books as they stand on the shelves. Stacks should never block air flow from existing windows or ventilation created by fans.

Stacks should be open backed, particularly free standing stacks which are joined at the back. This will improve the ventilation on all sides of the volumes. If strength or stability of the stacks is a concern, cross braces should be used rather than the solid panel supports provided in many commercially available stacks. Compact shelving, however desirable from the stand point of space saving, should be avoided in the tropics, primarily because a micro-environment may be created when the stacks are closed. In addition, the mechanisms for moving the stacks tend to become inoperable in high humidities.

Closed cabinets should be avoided whenever possible. If they are necessary for the storage of microfilm or locked case books both the back and front of the cabinet should be ventilated, or a favorable microclimate should be created in the closed cabinet to counteract the high relative humidity.

Localized Environmental Modification

In addition to taking advantage of natural conditions in modifying the overall building environment, there are various technological methods for modifying the environment in localized areas within the

library. In most collections there are materials which warrant special protection. Rare and valuable works, and items of particular historic importance are often included in this category. There is therefore a tendancy to want to create a special area within the library where these materials can be kept secure, and receive the benefits of a more nearly ideal environment. Localized environmental modification may be used in addition to the measures cited above, but should not be considered substitutes for the modification of environment in the building as a whole.

Monitoring Existing Conditions

Before attempting to alter the environment in a specific location, it is imperative that existing conditions be understood. This requires comprehensive monitoring of the existing environment. Information should be available for conditions at given locations at all hours of the day and for all seasons of the year. If air conditioning units are to be installed, it is important to be sure that the lower temperature will not cause an unacceptable increase in the relative humidity, either immediately or during certain seasons.

The most efficient way to monitor temperature and RH is the recording hygrothermograph which provides a 24 hour a day record for seven days at a given location. Several hygrothermographs will be needed, and a schedule should be established for moving them to various locations, so that information will be available for all seasons in all areas of the library. These instruments are relatively inexpensive, $300-500, and are cost effective in the long run. Alternatives include fixed and portable monitors with no recording capability. Thermometers, hygrometers, and hygrothermographs can give readings of temperature, humidity and temperature and humidity respectively, but provide no charts and must be monitored regularly by staff in order to give an overall picture of conditions. These require considerable staff time. Readings must be taken at a variety of locations, at specified times throughout the day (and the night) and the readings recorded in order to create an accurate chart for conditions in each given location.

Sling or motorized psychrometers are necessary for calibrating other monitoring equipment, and can be used for instant readings in problem areas.

Paper humidity indicator strips are of relatively little use in truly tropical climates. They almost always register in the pink (humid) range, and most indicate only very broad changes in relative humidity. Their best use may be in closed cases where a drier microclimate has been created, but they must be monitored regularly in order to be of use.

The equipment recommended above for monitoring conditions prior to an alteration in local environments is also essential in maintaining the desired environment, avoiding fluctuations, and assessing the cause of mold outbreaks should they occur. Acquisition and maintenance of these monitoring devices should be considered as a long term investment in collections care.

Air Conditioning

The term air conditioning, as used in this study, refers to the utilization of individual mechanical units to cool and filter air within a localized area of a building. Central plants which provide environmental control for the entire building are beyond the scope of this work. Air conditioning units fall into two basic categories: evaporative cooling and chilled water cooling.

Evaporative cooling is the simplest and least expensive system, however it is generally not suitable for areas with year round high temperatures and relative humidities.

Chilled water cooling units include a refrigeration device which lowers the air temperature, and a heating unit which warms the air slightly before it enters the room. In humid tropical climates, this procedure is critical, since the air introduced must be above the dew point to prevent an unacceptable increase in relative humidity. A change in temperature of only 1 F will result in a change in relative

humidity of 3%. The monitors that control this process are most important. There are various different types of monitors for this system, including wet-dry bulb control, similar to that of a psychrometer, and hair hygrometers similar to those used on hygrothermographs.[7] The cost of a refrigeration unit may be double the cost of an evaporative unit, and is considerably more costly to operate in terms of energy costs. There is often a tendancy to reduce operating costs by shutting down the heating unit. This inevitably results in severe environmental problems. If the unit is to be purchased and installed, it must be operated properly.

The kind of filtration chosen and the degree of recirculation desirable depend very much on local conditions. Filters should be cleaned or replaced on a regular basis. Not only will this improve the air filtration, it will result in more economical operation of the system. Electrostatic systems should be avoided because they produce ozone which can damage organic materials.[8]

One other consideration regarding the use of air conditioning units should be mentioned. Air introduced into a particular locale will, like water, find its own level. Cool air entering at or slightly above floor level will remain there while the warm air floats above it. Air conditioning units should be installed as high up in the wall or window as possible to achieve maximum circulation in the area. Stacks and cabinets should be positioned in such a way that they do not block the air flow.

Dehumidification

In humid tropical climates, dehumidification may be the most important factor in preventing mold growth. Its strongest challenger is good air circulation, not air conditioning. As noted above, air conditioning may make dehumidification even more necessary. Portable dehumidification units should be available in every library, and for some the installation of a permanent system may be necessary.

The most common methods of dehumidification are mechanical

dessicant units are usually restricted to larger, fixed installation systems. They are quite efficient, relatively easy to maintain, and might be considered by institutiions with severe, year round humidity problems. A system described by Gates will dry and circulate 1500 cubic feet of air per minute and remove up to 20 pounds (approximately 4 gallons) of water per hour.[10] Dehumidification using heated air is, in general, not appropriate in tropical climates, and of the three types is the most costly to operate.

The most effective and economical systems for warm climates are the refrigeration units. Moisture is removed from the air as it condenses on refrigerated coils. Portable units operate on the same principle, and require very little maintenance and energy. Most have very basic internal monitoring devices, and can be set to maintain a given level of relative humidity.

One of the major advantages of dehumidification systems is that they do not require the major duct work that airconditioning systems entail. According to Gates, wator vapor will migrate to the point of lowest moisture content.[11] Thus, even portable machines can be left in place and adequately dehumidify a room. In large areas, several machines will be necessary.

Creating Microclimates in Cabinets and Cases

A microclimate is any variation from the prevailing temperature and relative humidity of the surrounding environment. It may be either negative or positive in its effects and may occur unsolicited or be artificially induced and maintained.

It may, at times, be necessary to create a microclimate within the larger building environment. This could be occasioned by the nature of the materials, the necessity of protecting valuable items, or by the desire to remove them from a controlled environment and exhibit them in one that is uncontrolled. Microfilm, maps and documents stored in file cabinets are obvious candidates for microclimates in high humidity environments. While the incidence of mold growth can be reduced in the

collection as a whole through improved circulation, the closed metal cabinets designed for the storage of microfilm, maps and documents tend to retain moisture, especially if they are not frequently used. By artificially lowering their interior relative humidity a beneficial microclimate can be maintained.

A reduced humidity microclimate can be establised in a closed storage cabinet through the use of dessicants which abssorb moisture from the air. There are a number of products which can be used as dessicants. Two of the most readily available are silica gel (which is available in various grades) and is widely used in the U.S. and Europe, and Nikka pellets (also called Kaken Gel) which is used in Japan and the Far East. Nikka pellets have been found to be more effective than silica gel at humidities above 60%.[12] Silica gel often includes a color indicator which turns from blue to pink as moisture is absorbed and indicates when the material has reached its maximum absorption and must be reconditioned.

Before use, the dessicant must be conditioned to 0% relative humidity. This is done by heating the material in an oven to drive off moisture. The pellets or crystals can be reconditioned and used many times without losing their absorption capacity. After conditioning, the dessicant may be placed in the cabinets, either in trays in the base, or in small cloth bags in individual drawers. If the dessicant used is not a color indicator, a hygrometer or indicator strips must be placed in the cabinet to indicate when reconditioning is necessary. Once the cabinet reaches the desired humidity, and an equilibrium has been reached, the dessicant will require reconditioning less often. If the cabinets are used frequently, reconditioning may continue to be required at frequent intervals. The larger the quantity of dessicant used, the longer the microclimate can be maintained before reconditioning is necessary.

There is a great deal of literature available on the creation of microclimates, much of it dealing with the installation of exhibit cases and the packing and shipping of works of art, but virtually all of it is

relevant to the control of environments in closed storage cases or other fixed locations. Stolow's recent publication[13] contains information on state-of-the-art microclimates.

STACK MAINTENANCE

Routine cleaning and maintenance lack glamour in every library, however it is particularly important where environmental control is lacking. When natural ventilation is used to maintain adequate circulation, dirt and dust is a constant problem. Since these particles are hygroscopic, attracting and holding moisture from the air, and since they often contain nutrients required by molds, the constant cleaning of stack areas is essential in tropical climates. Vacuuming will also reduce, even if only temporarily, the number of spores on materials. In savanna climates, a thorough cleaning just before the rainy season may eliminate outbreaks of mold altogether.

A routine schedule for vacuuming of all books in the stacks on an annual basis (or as often as possible) should be established and maintained. Frequent inspection of the stack areas is also important, particularly little used sections and storage areas.

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V. FUNGICIDES AND FUMIGATION

Most librarians, archivists and museum personnel share a conviction that mold must be killed. It is perhaps more appropriate and effective to concentrate on prevention, inhibition and removal. As noted earlier, molds are admirably equipped for survival. Even a kill ratio of 99% "is an almost insignificant loss to a fungus which can produce hundreds of thousands of spores in a small colony started from a single spore."[1] Fungicides and fumigants broad ranging enough and powerful enough to achieve a 99% mortality for fungi are now known to be toxic to man as well. In considering the use of fungicides and fumigants for the prevention or treatment of mold growth, two basic facts should be kept in mind:

- All biocides are chemically reactive, i.e. they are capable of reacting with and altering materials to which they are applied.

- All biocides have some level of mammalian toxicity.[2]

The traditional chemical approach to biodeterioration involves two strategies. One strategy, fumigation, interferes with the vital activities of the organism. The other strategy, topical application of fungicides to an object, interferes with their consequences, that is with the chemical reactions of the organism and its substrate. The number of compounds in use today is fairly limited. They include certain metal derivatives, organic chemicals (of which the phenols are the most common), and certain organometal compounds.[3] While there is a certain amount of interest in, and testing of more exotic techniques,

including irradiation and the use of ozone, "we must not place too much reliance on the hope for brand-new biocidal agents as the solution to the problem."[4] Both irradiation and ozone have been found to be damaging to certain materials.

It should be noted that the first strategy, interfering with the vital activities of the organism, can be accomplished without recourse to chemical treatment. Modification of the environmental factors required for the growth of mold is at least as effective as chemical treatments, and certainly far safer for both personnel and materials.

FUNGICIDES

The term fungicide, as used in this study is limited to those biocides in a liquid medium applied directly to the surface of an affected item. The application may be intended either to prevent the growth of mold, or to kill the mold once growth has begun. Of the fungicides recommended in the literature, most have proved ineffective in terms of long term protection or deleterious to the materials themselves. Those which do seem to have some level of residual toxicity are now known to be hazardous to staff and users who may handle the materials later. Exposure may be by inhalation, ingestion, or adsorbtion through the skin. Warnings concerning the use of biocides should be rigorously adhered to, both with regard to the actual application and possible residual effects.

Beckwith, Swanson and Iliams conducted a comprehensive series of tests on biocides used a paper protectants and found that 28 commonly recommended fungicides were either ineffective in killing mold or damaging to paper. These included mercuric chloride, chloroform and formaldehyde.[5] As recently as 1971, a British Museum pamphlet on biocides for archival and library materials recommended both chloroform and formaldehyde.[6]

Thymol and orthophenyl phenol crystals disolved in alcohol are often recommended as topical fungicides. Indeed, both have been widely used in the conservation field. Their use has been radically curtailed

by recent studies showing that both can damage the eyes and upper respiratory system. Thymol is believed to be the more toxic of the two, affecting the liver, kidneys, central nervous system and the circulatory system as well.[7]

Of the fungicides recommended in the literature, only alcohol and orthophenyl phenol, at the strength commonly found in household cleaning products such as Lysol, are recommended for topical application and their use should be limited. Until more is known concerning the toxicity of orthophenyl phenol, the use of its crystalline form disolved in alcohol should be avoided. Any recommendations in the literature that are more than a few years old should be viewed with skepticism, since it is only in the last few years that the toxicity of a wide range of biocides has become a matter of concern. Research is still underway to establish precisely what levels of exposure may be acceptable.

It is a longstanding medical principle that one should treat the disease, not the symptom. The application of topical fungicides to items exhibiting mold growth is a classic example of treating the symptom, and fails to address the broader cause of the affliction. Items treated in this manner and returned to the same environment that produced the outbreak are very likely to develop recurring symptoms.

FUMIGATION

The term fumigation is used in this study to include any treatment which relies on exposure to the fumes or vapor of a biocidal compound to kill mold. The idea of fumigation is appealing to most librarians and archivists. It does not involve the treatment of individual items and is therefore not costly in terms of staff time. Large numbers of items can be treated at one time, in either fumigation chambers or by sealing areas of the building and fumigating entire collections. The reality of fumigation is far less appealing when considered in terms of its uncertain effectiveness, lack of residual protection, possible alteration or damage of materials, and toxicity to staff and users.

Methods of Fumigation

Fumigation may be carried out in various ways, using a variety of fumigants, some better than others, but all hazardous. If fumigation is necessary, it should be carried out by licenced professionals whenever possible.

Of the fumigation chambers commonly in use, those which incorporate a vacuum are most effective in eliminating mold. The vacuum allows greater penetration of the fumigant, and there is a possibility that it may also have adverse affects on the mold structure, removing oxygen required for growth and possibly rupturing the spores themselves. Vacuum chambers are however extremely expensive to purchase and install. Ethylene oxide is the fumigant most often used in vacuum chambers, and requires an additional chamber for the aeration of materials after fumigation in order to rid organic materials of residual toxins. Sulphuryl flouride is also used in vacuum chambers for the eradication of insects. It is not effective as a fungicide, and very little testing has been done regarding its toxicity and effect on organic materials.

Non-vacuum fumigation chambers are most often used with thymol and orthophenyl phenol vapors as the fumigant. Many institutions maintain small cabinets for fumigation of a limited number of items. Often these fumigation cabinets are improvised from old refrigerators or metal cabinets which were never intended for use as fumigation chambers. These improvised cabinets are particularly dangerous for staff exposed to them on a regular basis. Occassionaly there are recommendations in the literature that fumigation may be carried out in plastic bags. The standard plastic bag available for the disposal of household trash is not a vapor barrier, and cannot contain fumigation vapors effectively.

Fogging of entire areas is most often carried out by professional fumigation companies, and should never be attempted by untrained, unlicenced staff. If fogging is necessary, librarians should know precisely what fumigant was used, and scrupulously observe all restrictions regarding access to the area and exhausting the gas after fogging. Organic materials may retain toxic vapors and information

regarding hazards to staff and users should be obtained from the company carrying out the fumigation.

TOXICITY OF FUMIGANTS

In order that librarians and archivists may more accurately assess the relative hazards of fumigants which may be in use in their institution, the following general information is provided.

Ethylene Oxide

Ethylene oxide was developed in 1859. By the late 1920's it was in common use as a fumigant for grain, and by the 1950's was widely used in museums, libraries and archives. Ballard and Baer provide an excellent study of the history, use, effectiveness, and hazards of ethylene oxide.[8]

In 1984 the Occupational Safety and Health Administration (OSHA) released a new standard for exposure to ethylene oxide of 1 ppm. Based on animal and human data, OSHA has determined that exposure to EtO "presents a carcinogenic, mutagenic, genotoxic, reproductive, neurologic, and sensitization hazard."[9] Safety requirements for use of the gas include methods of exposure control, personnel protective equipment, measurement of employee exposure, training in use of the gas, (often a licence is required),, medical surveillance, signs and labels, regulated areas, emergency proceedures and record keeping requirements. The presence of EtO cannot be detected by humans without the aid of monitoring devices until it reaches a concentration of 300 ppm, far in excess of the OSHA standard.[10]

Ethylene oxide is known by a variety of other names, including dimethyl oxide, Carboxide, 1,2-Epoxythane, Oxyfume, Pennagas and Oxirane. It is highly flammable, and is usually used in a 10% concentration with a carrier gas.

Methyl Bromide

Methyl bromide is most commonly used in the fumigation of insect infestations, particularly against hard shell insects such as beetles.

It is not particularly effective as a fumigant for mold growth, but is occasionally used as one. It is a colorless, transparent, easily liquified gas. It is easily detected, having a strong, chloroform-like smell. It is highly toxic by ingestion, inhalation or absorption through the skin. The tolerance level established by OSHA is 5 ppm. Methyl bromide affects the central nervous system, respiratory system, skin and eyes. Acute effects usually occur 30 minutes to 6 hours after exposure and may include convulsions followed by death due to pulmonary and/or circulatory failure. Chronic effects are usually limited to the central nervous system and include muscular pains, visual, speech and sensory disturbances and mental confusion.

Methyl bromide should not be used for the fumigation of any protein based material, as it seriously damages the protein structure. Leather for example becomes black and brittle when exposed to methyl bromide fumes.

Methyl bromide is also known by the proprietory names Brom-O-Gas, Brozone, MeBr, Meth-O-Gas and Terr-O-Gas.

Sulfuryl Fluoride

Sulfuryl fluoride is most often used in the tropics for the fumigation of termites in building stuctures. It has very high penetration even without a vacuum. Like methyl bromide it is not known to be effective against mold, but is occasionaly used for that purpose. It is an odorless, colorless tasteless gas, and is usually available only to licenced fumigators. The OSHA standard is 5 ppm. It has not been tested extensively, and its carcenogenic and reproductive effects are unknown. It may be ingested by inhalation or absorbtion through the skin. Acute effects include nausea, vomiting and abdominal pain. Chronic effects include defects in bone and teeth, and in animals lung and kidney damage have been found.

Sulfuryl fluoride is most often available under the trade name Vikane.

Thymol

Thymol is a white crystal with a distinctive aromatic odor and taste. It is derived from thyme oil and may be mixed with camphor in its crystaline form. It is moderately toxic by ingestion and inhalation. Studies indicate that exposure to thymol vapors can affect the central nervous system and the circulatory system. No precise level for minimum exposure has been established.

Thymol is sometimes used in its gaseous form (produced by heating the crystaline form to release thymol vapor) as a fumigant for small quantities of materials. In order to be safely handled following fumigation, materials must be aerated, preferably in a fume hood. This removes any residual protection against mold growth, but renders the materials safe for staff and patrons. Staff members working with items immediately after fumigation, or in the area of the fumigation chamber should wear respirators approved for organic chemicals. Goggles and heavy weight, vapor barrier gloves should be worn when removing items from a chamber.

Orthophenyl Phenol

Orthophenyl phenol is considered slightly less toxic than thymol. The Merk Index lists it as a "slightly toxic irritant" when inhaled. It is however moderately toxic by ingestion. In its crystaline form it is a white or cream color and is soluble in alcohol. Several sources recommend the substitution of OPP for thymol whenever the latter is recommended. Relatively little testing has been done regarding the toxicity of OPP, and no exposure level is available.

In tests conducted by Haines and Kohler, orthophenyl phenol was found to be a not very effective fumigant. Of the seven fungi tested, fumigation with orthophenyl phenol failed to completely halt mold growth even after 10 days of continuous exposure to the vapors under controlled conditions.[11]

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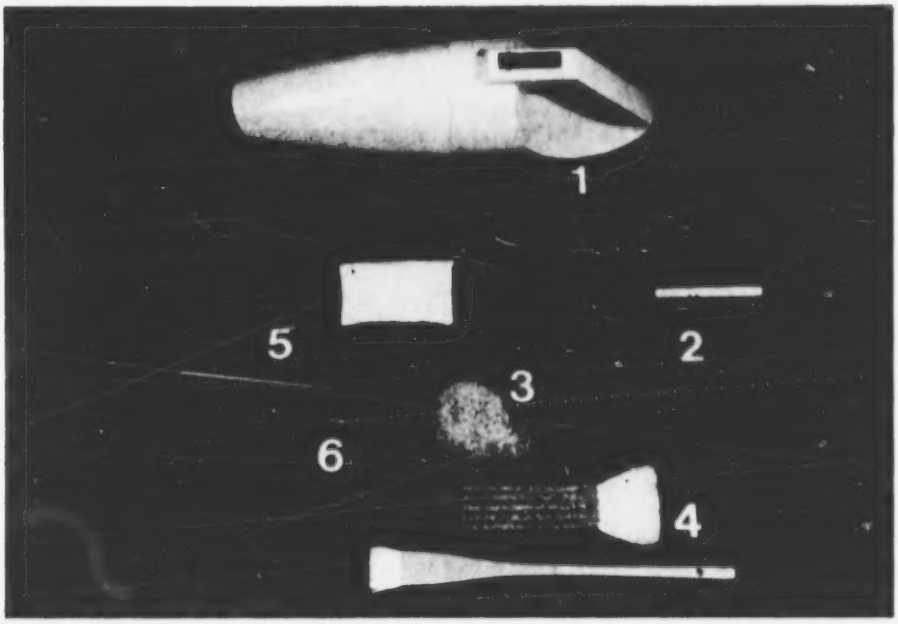
VI. TREATMENT

The most effective treatment in all but the most extreme cases is modification of the environment and removal of the mold growth from the affected item. Most mold outbreaks, if dealt with promptly, can be controlled without recourse to biocides. Fumigants should be necessary only in the most extreme cases, for example, a prolonged delay in beginning treatment following a major disaster. Even in this worst case scenario, options such as freezing, if available, may eliminate the need for fumigants entirely.

Selection of the appropriate treatment should be based on an analysis of the problem and the nature of the material. Different approaches will be required for different media, and different levels of treatment will be necessary depending on the size of the outbreak.

A variety of treatments will be discussed, many of them incorporating some form of vacuuming. It may be that the vacuum is one of the most important tools in the prevention and treatment of mold growth in tropical climates. The use of vacuum cleaners or vacuum aspirators to remove mold growth from the surface of items, is, in the author's view, preferable to other treatments currently available. The vacuum removes all elements of the colony (spores, conidiophores, and mycelium) and packages them neatly for disposal. It is non-toxic, and if used properly, does no structural or chemical damage to the item being treated. Vacuums are readily available everywhere, and are economical to operate. Even when electricity is not available, they can be operated with battery packs. The major disadvantage of vacuuming is that it requires handling each book individually and treatment is therefore labor intensive.

The equipment needed for the removal of mold growth as recommended in this study is quite basic, and should be readily available in most areas. It includes:



Illus. 5

Basic equipment and tools for the removal of mold growth. (1.)Portable vacuum cleaner with flexible hose and crevice tool for the removal of mold from book covers. (2.) Mini-vac for the removal of mold from paper surfaces. (3.) Powdered art gum eraser for cleaning the surface of paper too brittle to be vacuumed. (4.) Soft dusting brushes for the removal of art gum from the surface of paper. (5) Watercolor brushes with a fine point for removing mold from pastels and other fragile surfaces. (6) Fine pointed surgical tweezers which may also be used for removing mold from the surface of delicate materials.

This section will describe treatment for small, moderate and major mold outbreaks, and provide suggestions for treatment of specific categories of materials, including books, unbound paper, photographic materials and the general area affected. Readers should augment this information with materials included in the recommended literature on procedures for dealing with major disasters.

SMALL OUTBREAKS - LOCALIZED HIGH RELATIVE HUMIDITY

A small outbreak is here defined as the occurrence of mold on not more than a few hundred items. In a small outbreak, the mold affects only selected items or a specific area of the building, the materials are not actually wet, the mold growth having resulted from changes in the environment (usually an increase in the ambient relative humidity).

Treatment and modification of the environment should begin as soon as the mold is discovered. The delay of even a few days may turn a minor outbreak affecting only a few hundred items into a moderate outbreak affecting a few thousand.

Books

Small outbreaks of mold on bound materials are usually confined to the covers of books. They most often begin on the spine of the book, less frequently on the boards and around the turn-ins. Mold that occurs on the surface of book pages should be treated according to the recommendations for unbound materials below.

Mold growth should be removed from the covers of books by vacuuming, using small hand held or canister type vacuums with flexible hoses. The long slender attachment designed for cleaning crevices should be used, not the short round attachment with a brush. The brush attachment is not recommended as it will catch and hold the spores, conidiophores, and mycelium and prevent them from being drawn into the vacuum. The crevice tool will more effectively remove the growth by concentrating the pull of the vacuum on a relatively restricted surface area. A low power vacuum is best. One to one and a half horsepower is more than adequate. Large shop vacuums or wet/dry vacuums should not be used in the treatment of individual items.

The following procedures are recommended as a general guide:

- o The affected books and the surrounding area should be examined to determine which materials are affected and why.

- Temperature and relative humidity readings should be taken in the immediate area. These readings should be compared to records for that area to pinpoint any changes. If records do not exist, readings should be taken in unaffected areas near by. As soon as the nature of the problems is determined corrective measures to modify the environment should begin.

- Affected books should be handled as little as possible during removal from the stacks. Touching the mold will transfer the spores to worker's hands and press the mycelium down onto the book surface. Books should be placed on a book truck, standing upright as they did on the shelves. They should not be stacked or carried by hand, as this will spread spores and compact the mold colonies.

- Treatment of the affected books should be carried out in a work area where there is adequate light for close examination. As each book is removed from the truck, the mold should be vacuumed from the surface. The entire book should be cleaned thoroughly. The mycelium may be present beyond the obviously affected area, but not visible.

- If the book has a hollow spine, the back of the book block should be examined to determine whether there is mold growth inside the spine. A flashlight may be used to see down into the middle portion of the spine. If there is evidence of mold growth on either the spine lining or the adhesive, alcohol or a mild fungicide such as Lysol (which contains orthophenyl phenol) can be used to swab the inside of the spine and the back of the book block. A cotton swab on a long stick (wooden or bamboo barbeque skewers are useful) should be used to apply the fungicide. The book should then be placed upright in an open positon and allowed to dry thoroughly before the volume is closed and returned to the stacks. It is not advisable to use either alcohol or Lysol on the outer cover of the book. They may cause staining, changes in the color of the cloth, or loss of gilding. For mold on the outside of volumes, vacuuming is preferable.

- o Continue to monitor the conditions in the affected area with a psychrometer or recording hygrothermograph until it has been established that the problem has been corrected and conditions have returned to normal. Do not return treated materials to the stacks until the environment has been corrected.

Unbound Materials (Documents, Maps, Works of Art on Paper)

Mold may occur on unbound sheets of paper exposed to a high ambient relative humidity, or on materials in enclosed spaces (such as cabinets or glazed frames) where a microclimate has developed. Mold is less likely to occur on the pages of bound materials unless they are, or have been, wet.

Since single sheets of paper are not strong enough to withstand the pull of an average vacuum cleaner without damage, variations on the proceedures described above are required. Mini-vacuums designed for cleaning camera equipment, electronics and other delicate materials can be used to remove mold from the surface of documents without damage to the paper. If mini-vacs are not available, a vacuum aspirator can be improvised. (See Section VII. Equipment and Supplies).

The following procedures are recommended:

- o Affected items should be removed to a work room for treatment. If files are involved, the file folders should be placed upright in open boxes during the move.

- o The procedures for monitoring the environment described above should be followed.

- o Framed items should be removed from their frames and the mats and backing materials discarded. Any information on the mats or backings should be copied and retained. The glass should be cleaned thoroughly with glass cleaner or a dilute solution of household ammonia and water. The frame should be thoroughly vacuumed before reframing.

o Works of art on paper, documents and maps should be cleaned with the mini-vac or a vacuum aspirator. Both the front and back of the items should be cleaned. After vacuuming with the mini-vac, the surface of the item should be cleaned with powdered art gum eraser. The art gum residue should be brushed from the surface of the item after cleaning and should be vacuumed up with the hand held or canister vacuum.

Illus. 6

Audubon print with overall mold growth. Mold may occur on the surface of framed items. It can be removed using a vacuum aspirator or mini-vac if the paper surface is strong and the inks and pigments stable. Prompt removal will reduce the likelyhood of staining.

o If an item is very brittle the surface should <u>not</u> be vacuumed. Instead, reversing the procedure described above, powdered art gum eraser may be used to clean the surface. Cleaning should begin at the center of the item, and proceed toward the outer edges working in all four directions. The residue should be brushed off and vacuumed up. This will not remove the growth as

thoroughly as vacuuming, but will pick up most of the spores and mycelium.

o Works of art with pastel, chalk or other friable pigments should not be vacuumed. In such cases the mold must be lifted from the surface of the item using a fine pointed, stiff bristled brush. A head band magnifier or magnifying glass should be used in order to insure the removal of the mold and to prevent the disturbance of the surface. The mold picked up by the brush should be removed from the bristles after each area has been cleaned using the vacuum or mini-vac. Very fine pointed surgical tweezers may also be used to lift mold from the surface of delicate materials.

Illus. 7

Detail of pastel portrait with mold growth partially removed. Mold is selective, and the mold on this item occurred only on the black pigment used in the hair, eyebrows and eyes. The mold was removed with a fine pointed brush, without disturbing the surface of the image.

o If only the edges of file cabinet materials are involved, they can be vacuumed using the crevice tool described above. If mold growth is extensive, folders should be discarded. Information on the folder should be copied and retained with the items. The discarded folders should be placed in plastic trash bags and

removed from the area. Care must be taken to insure that the removal of the mold growth is complete. If there is any doubt regarding the extent of the mold growth, each sheet should be cleaned individually with the mini-vac as described below.

- o If the mold has developed in drawers, cabinets or other confined spaces the relative humidity must be lowered before items are returned to that space. The RH can be lowered by opening the drawers and cabinets and using fans to dry the interiors. Desiccants, placed in trays at the bottom of the cabinets may also be used in lowering the RH. If desiccants are used, they should be monitored and reconditioned when exhausted. If the problem seems likely to be a recurring one, the measures taken to correct the environment may have to be continued in order to maintain it. Desiccants are the most effective means of maintaining an acceptable RH in cabinets and drawers once it has been achieved.

Photographs, Negatives and Microfilm

The delicate emulsion surface of photographic materials makes the removal of mold more difficult, increasing the risk of damage to the image during the cleaning process. Prevention of mold is particularly important for such materials. In most cases, the development of mold on photographic materials is the result of a microclimate, and environmental conditions should be dealt with as above. In treating individual items, distinctions should be made between contemporary and historic materials. The commercial preparations available from photographic manufacturers for the removal or prevention of mold growth should not be used on historic materials.

- o Monitoring and modification of the environment should begin at once.

- o Storage boxes or envelopes with mold growth should be vacuumed thoroughly, or replaced if the growth is extensive.

- o The non-emulsion side of the carrier, i.e., the paper, plastic or glass should be cleaned first. Paper supports on photographs should be vacuumed according to the instructions for works of art on paper. Contemporary plastic films, including microfilm may be cleaned with alcohol on a cotton swab or with a commericial film cleaner according to the manufacturers instructions. Glass plate negatives should be cleaned with alcohol or dilute ammonium hydroxide, taking care that the solution does not come in contact with the emulsion surface.

- o Cleaning of the emulsion surface of negatives should be carried out on a light table. Mold should be lifted from the surface by lifting the mold from the surface using a fine pointed brush as described above in the section on pastel and chalk media. If there is any risk of damaging the emulsion further by cleaning, the mold should be left on the surface, and rendered dormant by using fans to dry the air and surface of the item.

- o The emulsion side of contemporary photographs may be cleaned with commercial film cleaners. Historic photographs should be cleaned according to the instructions for works of art on paper. Never use water based solutions on the emulsion of damaged photographs. If the fungus has softened the emulsion, water will remove it from the carrier.

General Area

In a relatively minor outbreak, improved air circulation is usually enough to bring down the relative humidity and lower the temperature in the immediate area. This may be accomplished by the use of fans alone, or by a combination of fans and dehumidifiers. Recurring problems may require the rearrangement of the area in order to improve air flow. The exact measures taken to correct a microclimate problem depend on the analysis of the situation at the time of the outbreak.

MODERATE OUTBREAKS - MAJOR AND PROLONGED PERIODS OF HIGH HUMIDITY OR MINOR FLOODING

A moderate outbreak is here defined as one involving a few hundred wet items or several thousand dry but moldy items located throughout the building. Two different courses of action are recommended depending on which of these conditions prevail.

Dry Moldy Items

For the treatment of mold resulting from prolonged periods of high humidity and affecting significant portions of the library collection, lowering the temperature and relative humidity through improved air circulation is the most viable option. Books should be vacuumed in the stacks if the number involved is too large to consider moving them to a treatment location. Cabinets and drawers should be opened and the contents vacuumed. They should remain open until the RH has reached an acceptable level and the situation is under control. Conditions should be monitored in all affected areas of the library. Any items that are felt to merit individual attention should be handled as described above in the section on minor outbreaks.

Wet Items

Detailed procedures for the salvage of large numbers of wet items has been covered in a number of publications. Two that are especially recommended are Procedures for Salvage of Water-Damaged Materials[1] and An Ounce of Prevention[2]. These recommendations should be followed for the handling and treatment of wet materials. The recommendations below will focus on the prevention of mold growth during the treatment and drying of items that are wet as a result of localized flooding.

Localized flooding may occur as a result of burst pipes, leaks in ceilings, walls or windows, or from backed up drains or flooding in the lower areas of the building. If the flooding involves water from rivers or any form of backup from drains, precautiions must be taken to protect workers from possible infection and disease.

Books

The recommendations below are intended as a general guide.

- Removal of wet items from the flooded area should be the first priority and should take place as soon as possible. Once the books have been removed, standing water should be removed. If left, it will contribute to continued high relative humidity throughout the area and may result in mold growth on items not directly affected by the flood. Water may be removed using pumps, wet/dry vacuum cleaners, or mops and buckets. Fans should be set up in order to lower the relative humidity and insure adequate air circulation.

- Wet items should be removed to a large dry area where fans can be kept in operation 24 hours a day to speed the drying and reduce the likelyhood of mold growth.

- Items should be dried on tables. Drying wet books on the floor should be avoided since circulation will be worst at floor level. If the drying process takes several days, materials on the floor will be more vulnerable to insect attack, and the handling of materials and movement around the room will be more difficult.

- Items should be constantly attended during the drying process. Pages should be turned and inter-leaving materials replaced frequently in order to insure relatively uniform drying. Inter-leaving papers should hung up to dry if they are to be reused. If they are to be discarded, they should be placed in plastic bags and removed from the area.

- As items dry they should be removed from the treatment room. Each item should be carefully inspected to be sure that it is completely dry before it is transfered to a storage area.

- If mold has developed it should be vacuumed off the items only after they are reasonably dry. No attempt should be made to vacuum very wet materials.

o If there are too many items for a limited staff to handle, or if there are delays in beginning the drying process for some items, freezing may be necessary.

Unbound Materials

o Wet items should be removed to the drying areas as soom as possible. Unbound sheets should be treated in a seperate area of the room from bound materials. This will allow better use of space and faster drying.

o Matting materials should be removed and discarded if this is possible without damaging the item.[3] Relevant information can be copied and retained with the item. If the item is mounted overall to board, no attempt should be made to remove it from the backing unless it is obvious that the adhesive is water soluble, and the item is already partially detached. If this is the case, the backing should be removed from the item a layer at a time. Do not attempt to lift the item from the backing. If items must be dried on backing boards, they should receive special attention during the drying process, since they will dry more slowly, and the adhesive may increase the possibility of mold growth.

o Individual sheets should be spread on tables to dry and turned frequently as soon as they are dry enough to be safely handled. If space is a problem, trays can be constructed from fiberglass screening and wooden frames, and stacked, provided that there is adequate space between them to allow air circulation.

o Rolled items should be carefully unrolled after they reach the drying area. Multiple items rolled together should be carefully separated for drying.

o Care should be taken in positioning fans. They should provide good circulation but not blow directly onto drying items. Partially dry papers can be lifted and torn by the draft from an improperly positioned fan. Air movement should be constant above and below the items, but not directly on them.

- o Documents in file folders may be dried upright in the folders if only the upper edges are wet. If the entire folder or the bottom fold is wet, they must be opened and the contents spread out to dry.

- o Materials should be removed from the drying room as soon as they are completely dry. If there is residual mud or evidence of mold growth they should be cleaned with the mini-vac and powdered art gum as described above.

For unbound paper items affected by flooding, freezing is usually not necessary. Since they will dry more rapidly, unbound paper should be attended to immediately, and materials which will require several days or weeks to dry should be chosen for freezing. These frozen items can then be dried in smaller increments as staff and space are available.

Photographs, Negatives and Microfilm

The gelatine emulsion on photographic materials is particularly vulnerable to water. The emulsion on black and white prints and negatives can tolerate approximately 3 days of immersion before the emulsion begins to separate from the support. Color prints and negatives begin to separate in only 48 hours.[4] Like unbound paper materials, these items should receive priority treatment, particulary with regard to removal from flooded areas.

- o Wet photographic materials should be removed from storage boxes or envelopes as soon as possible. The storage materials should be dried separately or discarded after relevant information has been copied.

- o Mud or debris on photographic materials should be removed by rinsing with clean water before drying. No attempt should be made to wipe or brush residue from the emulsion of wet photographic materials.

- o Microfilms should be unwound from their spools and clipped by their leaders to a line to dry. Flexible film negatives may be handled in the same way.

- o Photographs and glass plate negatives should be air dried lying flat with the emulsion side up. They should not be placed face down or turned over until the emulsion side is completely dry.

General Area

In most cases of localized flooding, the removal of standing water and the use of fans is sufficient to return the area to a functional condition. Conditions should be carefully monitored to insure that the relative humidity has returned to a safe level before items are returned. Materials should be checked frequently in the weeks after their return to the flooded area to detect any mold which may occur on items not completely dry.

Shelving and cabinets may be wiped down with alcohol or Lysol if there is evidence of mold growth on their surfaces. Sterilization of the area should be required only if the water is suspected of having been contaminated by sewage. Sterilization should be carried out by a qualified commercial fumigator, and staff and users should not return to the area until it has been thoroughly aired.

MAJOR OUTBREAKS - MAJOR FLOODING AND PROLONGED EXPOSURE

Major outbreaks of mold are generally associated, even in the tropics, with some form of natural disaster. Often the building is damaged, and support services such as power and water are unavailable. This can result in delays of days or sometimes weeks before salvage operations can begin. A well formulated plan for dealing with major damage to buildings and collections provides the best possible chance for salvage. Contacts with individuals and corporations which can provide needed materials and services must be made before the event occurs, or there will be virtually no chance of securing the necessary supplies. Contact numbers or addresses should include night and weekend numbers, since emergencies rarely occur during standard office hours. There is no substitute for a well formulated disaster plan.

Priorities and Planning

Decisions as to which portions of the collection are to receive priority in salvage operations must be made in advance. Materials which can be replaced should be sacrificed and attention given to those which are irreplaceable. Priority is usually given to unpublished manuscript materials, items of particular monetary or historic value, and materials of local or regional significance. Recent periodicals, items held by a number of other institutions and collections of peripheral importance to the function of the institution may be considered replaceable or expendable. Experience has shown that these decisions cannot be made at the time of the disaster when shock and despair tend to overwhelm staff and administrators. A disaster plan which details the priority accorded to specific parts of the collection can ensure the salvage of the most important items in even the worst circumstances.

The plan should include:

- Those portions of the collection that are to receive priority for salvage and treatment and the order in which they are to be removed.

- What form salvage will take for each, i.e., air drying, freezing or freeze drying.

- Who will be responsible for overseeing the salvage of each specific portion of the collection.

All staff members should receive enough training to supervise volunteers in salvage operations and lines of command and communication should be clearly drawn. Whenever possible, equipment and supplies required should be maintained by the library, including one or more generators, vacuums, fans, plastic milk crates and trays for the removal of wet materials, and a stock of heavy plastic, fiberglass screening and absorbent paper such as toweling or unprinted newspaper stock.

Sources of additional materials and facilities should be part of the disaster plan, and should be available to a number of senior staff members. Copies of the plan should be kept in locations outside the institution.

Whenever possible, basic salvage procedures including air drying and preliminary treatment should be conducted on site. The difficulties of moving masses of wet materials increases the risk of physical damage and reduces the number of personnel available on site to deal with any unanticipated problems. Only if the building is so extensively damaged that there is no covered, relatively dry space available should an alternate location be utilized. It is useful to have a back-up plan that incorporates access to an alternate site, but it should be used only if absolutely necessary.

As soon as there is access to the building, items should be removed in order of priority. Items removed to the air drying area or to freezers should be processed according to the literature for the salvage of materials. The recommendations which follow will focus on measures which may help to prevent mold growth on items awaiting removal and treatment.

Prevention of Mold Growth on Site

- Dry materials remaining in the area above the flood line should be removed if possible. They should be packed loosely in plastic milk crates and stacked in a dry, adequately ventilated area. They should not be placed in closed containers, since they will undoubtedly have absorbed moisture from the air and may become moldy if they are left in sealed containers.

- Standing water should be removed from all areas of the building as soon as possible.

- Fans should be set up as soon as the area is dry enough to allow the safe operation of electrical equipment, and should remain in operation continuously during the salvage operation. If

dehumidifiers are available, they should be used in conjuction with the fans.

- o If dry materials must remain in the stack areas, as soon as fans are installed, they should be separated on the shelves in order to increase circulation and speed the drying process.

- o Carpets and draperies, which retain water and contribute to maintaining a high relative humidity in the area, should be removed.

- o If the building is designed to take advantage of natural ventilation, windows should be opened as soon as possible to increase air cirulation throughout the building.

- o The building and materials should be frequently inspected to detect any signs of mold growth as soon as possible. If mold is discovered, every effort should be made to increase the air circulation in that area, and to lower the temperature and relative humidity.

Fogging of the area with a fumigant should be undertaken only as a last resort. There is no guarantee that fogging will prevent mold growth in the collection and relying on fogging alone may give a false sense of security. It may also prove hazardous to those who handle the material later in the salvage operation.

Freezing

In major disasters, air drying may not be possible for all of the affected materials due to time, space, and staff limitations. Freezing provides the best protection for wet materials which cannot be dried within a reasonable time. Items can remain frozen for months if necessary, while decisions are made regarding drying and treatment. If individually wrapped, they can be thawed and air dried in whatever quantity the staff and facilities can accomodate. Refrigerated containers of the type used by overseas shippers can be brought to the

site and maintained with external generators for as long as necessary. The use of commercial freezing facilities in the area may also be possible, however health regulations may not allow the use of a space which is ordinarily used for the storage of food products.

Drying

There are, at present, only three viable methods for drying large quantities of wet materials. Air drying, vacuum freeze drying and vacuum drying are the only proven methods. Each has advantages and disadvantages, and usually a combination of methods is necessary to deal effectively with the number of items involved in a major disaster. Experiments with microwaves and other exotic drying methods have proven less than satifactory, often causing additional damage to the materials.

Air drying, has been proven effective, given adequate space, environmental conditions and personnel, but is relatively slow and very labor intensive. Wet materials must be continually monitored and attended to insure that the items dry completely and in the shortest possible time. Ambient relative humidity must be lower than that of the materials, and air circulation must be good for air drying to be effective. When air drying is possible, it is recommended for first priority items. Air drying is usually not possible for all items in a major disaster, and the majority may have to be frozen to await drying at some future time.

Vacuum freeze drying is costly and requires specialized equipment. However, it has the advantage of removing water from pre-frozen items without thawing them, reducing distortions and the chance of mold growth. The water is sublimated directly from the solid to the gaseous state and is drawn off by the vacuum. It is the most effective method of drying large quantities of wet materials. Libraries and archives preparing disaster plans should check for the availability of such facilities in the area, and if possible make arrangements for their use in emergency situations. Freeze drying facilities are usually associated with food processing plants, and special permission from Health departments may be required for their use.

Vacuum drying removes water in its liquid state and previously frozen materials are partially thawed during the vacuum drying process. Warm, dry air is pumped into the chamber and water is drawn out by the vacuum. This process is considerably slower than vacuum freeze drying, and there is some risk of mold growth and further damage to water soluble materials. Vacuum drying also results in considerably more distortion of materials than vacuum freeze drying.

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3. Marilyn Kemp Weidner. Instructions on How to Unframe Wet Prints. Cooperstown, N.Y., New York State Historical Association Library, 1973.

4. Barton and Wellheiser, p. 69

VII. EQUIPMENT AND SUPPLIES

The following list of equipment and supplies is intended as a general guide. Much of the equipment is necessary for both the maintenance of the collection and in responding to emergency situations. These items should be purchased and maintained on site by the library. Other items are required only in emergencies and may be rented or leased. Institutions should identify local sources of equipment and supplies as part of a disaster plan. The Classified section of the phone book is an excellent source of information regarding sources of equipment and services.

MONITORING EQUIPMENT

Equipment for monitoring temperature and relative humidity should be standard equipment in every library. The number and type of monitoring devices necessary will depend on the size and specific needs of each institution. If only a limited number of monitoring devices can be purchased, they should be portable, and a regular schedule should be established to monitor all locations in the building. A psychrometer is required for the calibration of the other devices, and should <u>always</u> be included in the necessary monitoring equipment.

Psychrometers

Psychrometers measure temperature and relative humidity using a wet and dry bulb system. The dry bulb indicates the ambient temperature, and the relative humidity is determined by the difference between the wet and dry bulb reading. Manual and motorized models are available.

Hygrometers

Hygrometers measure only relative humidity. They do not record readings and must be monitored regularly by staff. They are available in wall mounted or free standing, portable models.

Hygrothermographs

Hygrothermographs measure temperature and relative humidity, but do not record and must be monitored by staff. They are available in wall mounted or free standing portable models.

Recording Hygrothermographs

The recording hygrothermograph measures and records temperature and relative humidity on a removeable paper chart. Machines may record 24 hours, seven days or one month. Both wall mounted and portable units are available.

See Classified Section under: Laboratory Equipment and Supplies
Scientific Apparatus & Instruments

PREVENTION

Most of the equipment necessary for the prevention of mold growth should be readily available from a number of sources.

Fans

A variety of different fans may be necessary in order to effectively modify the environment and provide adequate air circulation and ventilation. Permanent installations in walls, ceilings and windows should be supplemented by portable fans which can be moved to problem areas of the building as needed. Fans are also necessary during emergencies, both to maintain air circulation in drying and treatment areas and to increase air circulation in flooded areas during the removal of water damaged materials. Libraries in tropical areas cannot have too many fans.

See Classified Section under: Fans-Electric
Fans-Ventilation and Exhaust
Ventilating Equipment

Vacuum Cleaners

For routine cleaning and maintenance of collections, portable cannister or hand held vacuum cleaners are recommended. They should be equipped with a flexible hose and a variety of attachments. For general cleaning, the brush attachment may be used. For the removal of mold the crevice tool is recommended. Vacuums used for cleaning items from the collections should be no more than one to one and a half horsepower.

Dehumidifiers

Dehumidifiers may be either permanently installed or portable. The permanent systems will in general be more effective and cost efficient, but more expensive to install. Portable systems are useful in correcting localized problems and in emergency situations. The type of system chosen will depend on the prevailing environmental conditions as established by a monitoring program prior to purchase.

See Classified Section under: Dehumidifying Equipment
Dehumidifying Chemicals

Desiccants

Desiccants are useful in humid tropical climates for maintaining microclimates within cases and cabinets. A variety of types and absorbencies are available, from scientific and chemical suppliers. Silica gel is widely used in the United States and Europe. Nikka pellets are more widely available in Asia. Desiccants should not be placed in direct contact with books or papers, but should be contained in trays or fine mesh cloth bags.

See Classified Section under: Dehydrating Chemicals
Drying Compounds
Silica Gel

Air Conditioners

Lowering the temperature at which collections are stored is beneficial in terms of prolonging the life of paper and other book

materials, but can cause problems in areas where relative humidity is high. Before air conditioning is installed, conditions must be carefully monitored to insure that relative humidity will not increase to dangerous levels. Local heating and cooling specialists should be consulted in order to determine which available equipment can most successfully modify both temperature and relative humidity.

See Classified Section under: Air Conditioning Equipment & Systems
Air Conditioning-Room Units
Ventilating Contractors

Air Quality

Filtration of air to remove particulate matter can reduce the incidence of mold growth, but cannot eliminate it completely. Local ventilation specialists should be consulted in order to achieve the maximum filtration possible without interfering with air circulation.

If fumigation is carried out on site, monitors which can give accurate readings of the level of toxic vapors remaining on site or in the materials are necessary.

See Classified Section under: Air Cleaning and Purifying Equipment
Bacteria Control Systems
Filters - Air

TREATMENT

The equipment necessary for the removal of mold growth should be acquired and maintained in working order in every institution in the tropics. At least one staff member should be trained and delegated to take charge of any treatment and to supervise other staff members in the event of a moderate or major outbreak.

Vacuum Cleaners

Low power hand held or cannister vacuums should be used in removing mold from the covers of books. The crevice cleaning tool should be used rather than the brush attachment. The vacuums chosen should have

disposable paper collection bags, not reusable cloth bags. See Prevention above.

Mini-Vacuums

Mini-vacs are used for the removal of mold from the surface of paper. They are most useful where mold is an infrequent occurance. Most models may be operated by either direct electric power or with batteries. They are available through camera and electronic equipment suppliers.

Vacuum Aspirators

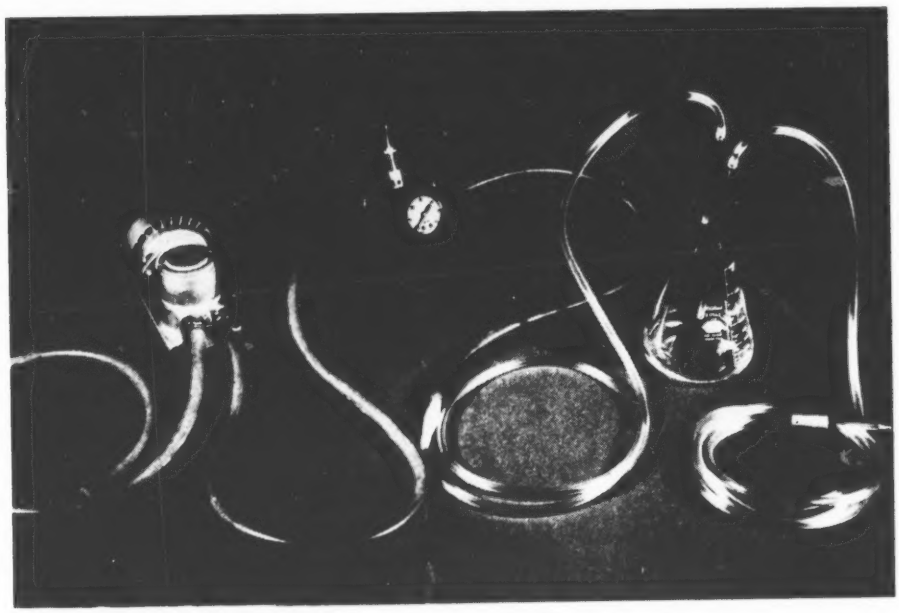
Vacuum aspirators, like the mini-vacs are used for the removal of mold colonies from the surface of both books and paper. They are more effective than the mini-vacs, and are a worthwhile investment where mold is a recurring problem.

Vacuum aspirators are relatively easy to construct, and require:

1. A small vacuum pump with regulator.
2. A 3' length of clear plastic tubing of appropriate inner diameter to fit the vacuum pumps intake port.
3. Two sections of 1/4" inner diameter glass tubing, one approx. 8" long and the other approx. 4" long.
4. A 1000 ml Erlenmeyer flask.
5. A two hole rubber stopper for the mouth of the flask.
6. A 5' length of clear tubing of appropriate inner diameter to fit the glass tubing.
7. An eye dropper with the suction bulb removed.

Clear plastic tubing is preferable, as it can be monitored for the build up of spores on the inner wall of the tubing and changed as necessary. Opaque rubber or plastic tubing may be substituted if clear tubing is not available. If the air intake port and the glass tubing differ in size, tubing of appropriate size may be joined with plastic tube connectors.

The aspirator is assmbled by attaching the 3' length of tygon tubing to the air intake valve on the vacuum pump regulator. The other length of the tube is attached to the 4" glass tube and this is inserted into one of the holes in the rubber stopper. The 5' length of tubing is attached to the 8" glass tube, and the tube is inserted into the other hole in the rubber stopper. The stopper is then placed in the mouth of the flask. The large end of the eyedropper is inserted into the unattached end of 5 ' tubing. The eyedropper and the length of tubing form a tiny vacuum cleaner. The mold is collected in the flask. The mouth of the eyedropper should be smooth, and may be sanded with emery paper if there are any irregularities. When the vacuum pump is plugged in, the pull of the vacuum may be regulated by adjusting the intake valve.



Illus. 8

Vacuum aspirator. Vacuum pump at left, regulator center and flask, tubing and eyedropper at right.

In an emergency, when electrical power may be off for days or weeks, a vacuum aspirator can be improvised using a water tap. A special attachment (called a water-jet pump) is necessary for the tap, and can be obtained from chemical suppliers. A vacuum is created by the flow of water through the faucet, and the pull of the vacuum can be

regulated by increasing or decreasing the volume of water. The 3' length of flexible tubing should be attached to the side opening of the water-jet pump and connected to an Erlenmeyer flask as described above. Any local university or high school chemistry department can provide assistance in constructing a vacuum aspirator. They are quite simple to set up and use, but rather difficult to describe.

See Classified Section under: Laboratory Equipment and Supplies
Scientific Apparatus and Instruments

Magnifiers

The use of a magnifier will aid in the thorough removal of mold growth. A disecting microscope with a long arm adjustable stand is best, but will not be available to most libraries. A headband magnifier provides an acceptable level of magnification, and leaves both hands free. Hand held magnifying glasses may be used if no other apparatus is available.

See Classified Section under: Microscopes
Magnifying Glasses
Artists Materials and Supplies

Brushes

An assortment of brushes will be needed. Fine pointed artist's watercolor brushes should be used for removing mold growth from the surface of pastels and other fragile media. Wide dusting brushes of rabbit hair should be used for routine cleaning and the removal of powdered art gum eraser. These dusting brushes should not be used in the removal of mold growth.

See Classified Section under: Artists Materials and Supplies

Powdered Art Gum

The use of powdered art gum for the removal of mold growth from fragile paper is recommended. Powdered art gum is available through most art and drafting supply stores. If it is not available locally in

powdered form, art gum erasers can be cut into small squares and reduced to powder in a household blender. Several different grades or sizes can be made, from relatively coarse to very fine. The larger grains should be used first in order to pick up the mycelium from the paper, followed by the finer grain powder to remove remaining spores.

See Classified Section under: Artists Materials and Supplies
Drafting Room Equipment and Supplies

Tweezers

Very fine pointed disecting or surgical tweezers may be used for lifting mold from fragile surfaces and pastels.

See Classified Section under: Laboratory Equipment and Supplies
Scientific Apparatus and Instruments
Physicians and Surgeons Equipment and Supplies

EMERGENCY TREATMENT

Sources of supplies and contact persons for emergency equipment should be located prior to an emergency, and lists and phone numbers should be kept in several places in and outside the library.

Pumps and Water Removal Equipment

Pumps and wet/dry vacuums should be available for the removal of standing water after floods. Such equipment can sometimes be rented, and sources should be located during the development of a disaster plan.

See Classified Section under: Rental - Equipment and Tools
Rental Service Stores and Yards
Listings for specific items - Rental

Freezing and Cold Storage Facilities

Cold storage facilities may be used in emergencies, but prior contact is usually necessary, and immediate access is often not possible. The use of refrigerated shipping containers for the freezing and storage of water damaged materials may be more viable.

See Classified Section under: Warehouses - Cold Storage
Cargo & Freight Containers
Trucking
Truck Renting and Leasing
Truck Refrigeration Equipment

Vacuum Freeze Drying and Freeze Drying Equipment

Commercial food processors are the usual source of such equipment and services, but may not exist in all areas. For relatively small numbers of items (under 1000) home frost-free freezer units may be used. Larger, commercial frost-free freezer units may also be available.

See Classified Section under: Foods - Dehydrated - Whol & Mfrs
Refrigerating Equip - Commmercial
Refrigerators and Freezers - Dealers

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